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MEMORANDUM

TO: All Interested Parties

SUBJECT: Release of EPA Report "MTBE-Oxygenated Gasolines and Public Health Issues"

FROM: Mary T. Smith, Director
Field Operations and Support Division

Please find enclosed a copy of the EPA report "MTBE-Oxygenated Gasolines and Public Health Issues." This is a report summarizing information currently available regarding MTBE health effects.

The report was written by EPA's Office of Research and Development in Research Triangle Park, N.C. The evaluation was conducted by the Environmental Criteria Assessment Office (ECAO), led by Dr. Judith Graham.

This report comprises just one part of a much larger Agency effort to investigate the potential effects of using MTBE as a gasoline additive. The investigation has been prompted by citizen complaints in Alaska and Montana. FOSD is presently cooperating with Region X, Region VIII, ORD, the Office of Pesticides and Toxic Substances, the State of Alaska, the Centers for Disease Control and industry on this effort.

If you have any questions regarding this report or EPA's ongoing studies regarding the use of MTBE-blended gasoline, please contact Alfonse Mannato of the Regional/State/Local Coordination Section of FOSD. His phone number is (202) 233-9308.

MTBE-OXYGENATED GASOLINES AND PUBLIC HEALTH ISSUES

Office of Research and Development
U.S. Environmental Protection Agency

1. INTRODUCTION

The Clean Air Act Amendments of 1990 require the use of oxygenated gasoline in the 39 areas of the country that exceed national health standards for carbon monoxide (CO). Carbon monoxide pollution is caused by incomplete burning of fuels used in internal combustion engines and is generally more severe during cold winter temperatures. That is why the oxygenated gasoline program covers just the typically coldest winter months in areas exceeding the CO standards. Gasoline was changed by adding oxygenates, such as ethanol or methyl tertiary butyl ether (known as MTBE), and reducing certain other organic compounds. The expected result is decreased emissions of CO and some other toxic air pollutants (e.g., benzene). However, some degree of trade-offs are also expected to be necessary between (1) the expected reductions in CO, benzene, etc., and (2) increased emissions of MTBE and, possibly, certain other substances (e.g., formaldehyde).

This report was developed at the request of U.S. Environmental Protection Agency (EPA) Regions 8 and 10 and the Field Operations and Support Division of the Office of Mobile Sources. The request was prompted by public health issues raised by the State of Alaska and health complaints by the public in Missoula, MT, both of which are using oxyfuels with approximately 15% MTBE. Therefore, the following discussion summarizes the current scientific information about potential health risks of CO, MTBE, and a few other air pollutants associated with use of oxygenated gasoline containing approximately 15% MTBE versus conventional gasolines. Oxyfuels with MTBE are widely used. There were seven areas that required oxyfuels before 1992. The Denver, CO, program began in 1988, and five of the other programs have been operating since 1989. The Phoenix, Tucson, and Denver programs have had a market share for MTBE of at least 80%. Independent of the oxyfuels program, regular gasoline in most areas of the country has had a lower level

(2 to 4%) of MTBE, and a significant portion of premium gasoline has had from 6 to 11% MTBE. In these cases, MTBE is used as an octane enhancer.

The discussion is organized in four sections: (1) health effects; (2) emissions, air quality, and exposures; (3) a summary about potential risks that integrates current knowledge of health effects and exposure; and (4) a summary of short-term research needs and programs. This report is not intended to be a complete national evaluation of MTBE oxyfuels. Rather, it focuses on Alaska-related issues, insofar as the information permits. Much of the information, however, has a cross applicability to other areas of the country.

2. HEALTH EFFECTS

Throughout, it is important to understand that conventional gasoline with very low levels of oxygenates can cause health effects, and that health effects are related to the levels and duration of exposure. All chemicals have different types and degrees of health effects. However, these are of public health concern only above certain exposure concentrations, which are different for each chemical. Variations in exposure durations and patterns are also very important in determining the nature and severity of potential health effects. For example, short-term exposures to a chemical can cause different effects from long-term exposures. The level of physical activity (exercise) being performed during the time of exposure and the health status of the person being exposed can also influence the degree of health effects caused by each chemical. This section focuses on the nature of potential health effects, not exposure or consequent risks.

2.1 Carbon Monoxide

The Clean Air Act directs the Administrator of the EPA to establish National Ambient Air Quality Standards (NAAQS) for several widespread air pollutants, based on scientific criteria and allowing for an adequate margin of safety to protect public health. The CO NAAQS is 9 ppm for an 8-h average and 35 ppm for a 1-h average; neither is to be exceeded more than once per year. So many U.S. citizens are potentially exposed to CO that Congress made its reduction a national priority by requiring [Section 211(m) of the Act] oxygenated gasoline programs in cities that do not attain the CO NAAQS, beginning on November 1, 1992.

The EPA has documented the detrimental health effects that CO can have on populations (U.S. Environmental Protection Agency, 1992). Carbon monoxide is a colorless, odorless, and nonirritating gas that is readily absorbed from the lungs into the bloodstream, there forming a slowly reversible complex with hemoglobin (Hb) known as carboxyhemoglobin (COHb). The presence of COHb in the blood reduces the amount of oxygen available to vital tissues, affecting primarily the cardiovascular and nervous systems. Although the formation of COHb is reversible, the elimination half-time is quite long because of the tight binding between CO and Hb. This can lead to accumulation of COHb, and extended exposures to even relatively low concentrations of CO may produce substantially increased blood levels of COHb.

The lethality of CO that results from exposure to very high concentrations is well known. Effects in individuals suffering from acute CO poisoning cover a wide range, depending upon severity of exposure: headache, dizziness, nausea, vomiting, collapse, coma, and death. Such effects only occur, however, at very high COHb levels (in excess of 10%) associated with at-rest exposures to markedly elevated CO air levels (e.g., greater than 300 ppm for 1 h or greater than 80 ppm for 8 h), as may occur in accidental CO poisoning cases in homes or vehicles with faulty or inadequately vented combustion sources.

The effects of exposure to low concentrations—such as the levels found in ambient air—are far more subtle and considerably less threatening than those occurring in frank poisoning from high CO levels. Maximal exercise performance in healthy individuals has been shown to be affected at COHb levels of 2.3% and greater. The reductions in performance at these levels are small and are likely to affect only competing athletes rather than people engaged in the activities of daily life. Central nervous system effects, observed at peak COHb levels of 5% and greater, include reduction in visual perception, manual dexterity, learning, driving performance, and attention level. Of most concern, however, are adverse effects observed in individuals with chronic heart disease at COHb levels of 3 to 6%. At these levels, such individuals are likely to have reduced capacity for physical activity because they experience chest pain (angina) sooner. Exercise-related cardiac arrhythmias have also been observed in some people with chronic heart disease at COHb levels of 6% and may result in an increased risk of sudden death from a heart attack. Carboxyhemoglobin levels (3 to 6%) of concern for induction of cardiovascular effects among people with chronic heart disease would be expected, on average, with exposures during light exercise to CO ambient air concentrations of 60 to 100 ppm (1 h) or 20 to 45 ppm (8 h).

The NAAQS set by EPA are intended to keep COHb levels below 2.1% in order to protect the most sensitive members of the general population (i.e., individuals with chronic heart disease). However, elderly people, pregnant women (due to possible fetal effects), small children, and people with anemia or with diagnosed or undiagnosed pulmonary or cardiovascular disease are also likely to be at increased risk for CO effects.

2.2 Air Toxics

Toxic chemicals in the atmosphere comprise a broad class of compounds, including numerous chemicals emitted from vehicles due to evaporation (e.g., during refueling) and due to fuel combustion (when the car engine is running). The air toxics of greatest current interest are MTBE (the oxygenate used in Fairbanks, Anchorage, Missoula, and many other U.S. cities in the oxyfuels program), benzene, 1,3-butadiene, and formaldehyde. Other fuel-related air toxics exist, but some are considered of minor significance for direct health effects. Since November, 1992, there have been a number of complaints of health-related symptoms in Fairbanks and to a lesser extent in Missoula and Anchorage. Many people automatically assume that these complaints are directly related to emissions of MTBE itself because its distinctive odor makes it readily identifiable. However, there are a number of chemicals emitted from vehicles using oxygenated and nonoxygenated fuels, and the specific cause of the reported symptoms is not yet known.

A major uncertainty in assessing the Fairbanks situation is the potential impact of a subarctic climate on emissions. Most previous studies have centered on more temperate conditions, and no extensive subarctic testing of any gasoline components has been conducted. However, the experience of Colorado, where MTBE fuels have been used during winter months (with subzero winter temperatures) since 1988, may be useful, along with new studies now underway, in understanding the influence of low temperatures on emissions.

2.2.1 MTBE

Odor Thresholds and Dermal Effects

To many people, the odor associated with MTBE oxyfuels is distinctly different from that of gasoline not containing MTBE. Odor threshold studies indicate that MTBE can be detected at very low concentrations. Odor is a characteristic of numerous chemicals, but it alone does not indicate toxic effects. For example, some toxic chemicals have no odor. Although the strong smell of MTBE may lead one to think that there are very large concentrations of it in the air, this is not necessarily true. It is wise to limit exposure to all automobile fuels. Thus, an aversion to the peculiar odor of MTBE may serve to limit exposure to all types of gasoline fumes.

Direct exposure of the skin to MTBE causes skin irritation similar to that of conventional gasoline (U.S. Environmental Protection Agency, 1993). Prolonged or frequent contact with either conventional gasoline or MTBE oxyfuel may result in drying, chapping, or cracking of the skin. If both types of fuels come into contact with the eyes, eye irritation may result. Because each of these effects potentially linked with skin exposure to MTBE-blended gasoline is also linked to exposure to conventional gasoline, normal precautions should apply when handling any type of gasoline, regardless of type or oxygen content.

Short-Term Exposure Effects

The effects of short-term exposure to MTBE are difficult to evaluate at present because little information is available. Humans are also acutely exposed to MTBE as part of a medical treatment to dissolve cholesterol gallstones (Leuschner et al., 1991). Injection of the gall bladder with a high dose of MTBE can be associated with several types of health effects (e.g., nausea, vomiting, sleepiness). This type of treatment is obviously quite different from an inhalation exposure related to MTBE oxyfuels due to differences in exposure route and concentration. These differences prevent direct extrapolation of high-concentration injection effects to the low-concentration inhalation effects. Nevertheless, it is important to note that MTBE is being used therapeutically in humans at high acute doses.

In rats, when inhaled MTBE is absorbed into the body, 99% of it is eliminated in 4 h (Ferdinandi et al., 1990). Laboratory rats exposed for 6 h to high concentrations of MTBE (2,900, 14,400, or 28,800 mg/m^3) experienced several types of effects (U.S.

Environmental Protection Agency, 1993). Activity levels in male rats were increased at 2,900 and 14,400 mg/m^3 and decreased at 28,800 mg/m^3 during the first hour following exposure; female rats showed similar but statistically insignificant effects. At the two highest levels tested, effects on the nervous system were observed and included increased lacrimation (tearing), decreased muscle tone, and staggered walking. Recovery occurred soon after exposure stopped. These studies indicate that short-term exposure to MTBE can cause reversible effects on the nervous system. However, the endpoints used in the rodent study would not detect the kind of symptoms reported by some Fairbanks, Anchorage, and Missoula residents. Additional research would be needed to clarify the effects of acute exposure to MTBE on the nervous system and whether sufficiently high exposures would occur to induce such effects.

In November and December of 1992, the Centers for Disease Control (CDC) undertook a field epidemiology study in Fairbanks (Moolenaar and Hefflin, 1992). Due to the time constraints of the study, there were inherent limitations to the extent of the health questionnaire and the number of people interviewed. Also, because all the gasoline in the area contained elevated MTBE, there was no group that could be considered a control having no exposure. Other potential confounders (e.g., bias due to odor, publicity about health complaints, negative attitudes about MTBE unrelated to health) cannot be ruled out. Initially, the CDC contacted 34 people who called the Fairbanks hotline with health complaints. They used information from these people to establish a "case" definition (i.e., the presence of symptoms such as headaches, cough, nose or throat burning, eye irritation, nausea, dizziness, etc.). The CDC then administered a symptom questionnaire by telephone to a random sample of 41 residents and found that 41% of the participants were cases (i.e., reported the presence of the case symptoms). The CDC reported that there was a statistically significant relationship between having health complaints and traveling in a vehicle or pumping gasoline.

Using questionnaires similar to those described above, the Alaska Department of Health and Social Services conducted further studies of three groups of people in Fairbanks presumed to have tiered levels of exposure: (1) taxi drivers, (2) health care workers who typically commute, and (3) university students with less time around vehicles (Beller and Middaugh, 1992). A similar study in Anchorage included three groups (taxi drivers, health center employees, and hospital employees) (Chandler and Middaugh, 1992). Analysis of the Fairbanks data in Table 1 showed that there was a statistically significant difference between the number of cases among the taxi drivers and health care workers compared to students. The statistical analysis of the Anchorage data was not reported, but it was stated that the taxi drivers had a higher proportion of complaints. In both cities, headaches were the most common symptom reported. The headaches were generally of short duration. In Fairbanks, there was not a significant increase in hospital emergency room visits for headache, implying that the complaints were not severe and were not resulting in widespread serious morbidity. In both cities, there were more symptoms reported during traveling than during refueling. The CDC also took blood and air samples in Fairbanks for later chemical analysis, but all results are not yet available.

TABLE 1. PERCENTAGE OF CASES IN FAIRBANKS AND ANCHORAGE

Interviewees	Fairbanks	Anchorage
Taxi drivers	33% (4 of 12)	46% (12 of 25)
Health care workers	29% (26 of 90)	
Students	15% (15 of 101)	
Health center workers		25% (7 of 29)
Hospital workers		27% (29 of 108)

Source: Beller and Middaugh (1992); Chandler and Middaugh (1992).

Because of the limitations of the epidemiology studies, the findings must be considered preliminary. The results do not provide definitive evidence that the use of MTBE oxyfuels caused the reported symptoms. However, the data from the two cities, the similarities of the findings, and the increases in complaints by individuals likely to have higher exposure suggest a potential for an impact on public health. If these symptoms are occurring, the data further suggest that they are generally acute, mild, and of short duration. It must be emphasized that further research would be required to determine whether there actually is an increase in symptoms and, if so, whether they are causally associated with oxyfuels with MTBE. Such information would also need to be compared and contrasted with potential risks for CO to impact public health in order to more fully evaluate relative risks of acute exposure.

Insofar as EPA is aware, there are no other available acute epidemiology studies of MTBE oxyfuels. In Fairbanks, Missoula, and Denver, there are publicized hotlines that solicit comments, thereby facilitating communication about complaints. People in Fairbanks and, to a lesser degree, Missoula made their health complaints public through these hotlines. On the other hand, in Denver, where oxyfuels with 8% MTBE were introduced in 1988, there were a number of complaints about odor and health symptoms (28 out of a total of about 2,670 nonhealth complaints) initially (Livo, 1993). However in the 1990-91 winter season, in which oxyfuels contained about 14% MTBE, there were almost no odor or health complaints made to a publicly advertised hotline. The presence of hotlines introduces confounding factors that make it difficult to interpret the meaning of complaints. Individuals in other areas having MTBE oxyfuels have not made mass health complaints, but all areas in the MTBE oxyfuels program do not have such hotlines.

Long-Term Exposure Effects

Pursuant to a 1987 consent order under the Toxic Substances Control Act, EPA required that industry conduct extensive studies of the health effects of MTBE in laboratory animals to estimate potential effects in humans. The studies evaluated all major organ systems using routine types of methods and included tests for reproductive and developmental effects. In 1991, EPA evaluated the noncancer chronic effects of MTBE and developed a health metric called an inhalation reference concentration (RfC) (U.S. Environmental Protection Agency, 1993). This RfC is 0.5 mg/m^3 MTBE. An RfC (for any chemical) is defined as an inhaled concentration, with an uncertainty spanning about an order of magnitude, that can be inhaled over a lifetime by people, including sensitive populations, that is thought not to pose any appreciable deleterious noncancer hazard. The current RfC is based on studies of rats exposed to 2,900, 14,400, or 28,800 mg/m^3 MTBE for 6 h/day, 5 days/week for 13 weeks. There were no noticeable effects on some of the parameters or organs studied, such as the lungs. However, the overall weight of evidence indicates that the 14,400-mg/m^3 level was moderately adverse to several organ systems in the rats, as indicated by decreased brain length; increased relative kidney, adrenal, and liver weights; and decreased body weights. The no-observed-adverse-effect level in the rats was 2,900 mg/m^3. In developing the RfC, this value was adjusted downward to account for uncertainties in the information available. Other studies were considered in the overall evaluation, including reproductive and developmental tests (U.S. Environmental Protection Agency, 1993). A two-generation reproductive study in rats found no effects at 1,400 mg/m^3; at 10,800 mg/m^3, the rat pups (in both generations) had reduced body weights and weight gains during postnatal development. High concentrations of MTBE did not cause birth defects in rats (11,900 mg/m^3) or rabbits (28,900 mg/m^3). Exposure of pregnant mice to 14,700 mg/m^3 MTBE caused developmental effects (skeletal changes and reduced body weight). This exposure was also maternally toxic, as indicated by reduced activity, staggered walking, reductions in body weight, etc. A lower concentration (3,700 mg/m^3) did not cause birth defects.

Recently, results of two long-term laboratory exposure studies have been provided to EPA, and the summaries were reviewed for this report (Burleigh-Flayer et al., 1992; Chun et al., 1992). In two separate studies, rats and mice were exposed to 1,450, 10,800, or 28,800 mg/m^3 MTBE for 6 h/day, 5 days/week for 18 mo (mice) or 24 mo (rats). Both cancer and noncancer tests were performed. The noncancer effects were similar to those of the 13-week study; the brain, kidney, and liver were major target organs impacted (e.g., increase in relative weights), and effects observed at the lowest concentration tested were either considered unrelated to the MTBE exposure, were compensatory in nature, or were unique to the species tested. Therefore, the no-observed-adverse-effect level in the chronically exposed rodents was 1,450 mg/m^3. When these newer data are incorporated into a reanalysis of the RfC, it is possible that the RfC will be increased because the original analysis incorporated extra caution in the absence of chronic data; with actual chronic data, uncertainty is reduced, and the RfC may change upwards. However, until the reevaluation is completed, the current RfC should be used.

The EPA is currently performing a full evaluation of the cancer tests in the chronic study mentioned above. For this report, the summaries of two chronic animal cancer bioassays of MTBE were evaluated (Burleigh-Flayer et al., 1992a; Chun et al., 1992a). Four groups of mice (males and females) were exposed 6 h/day, 5 days/week for 18 mo to either filtered air or MTBE at concentrations of 1,400, 10,800, or 28,800 mg/m^3. Four groups of male and female rats were exposed to the same conditions for 24 mo, except for the males of the 10,800- and 28,800-mg/m^3 groups (which were autopsied early due to excessive mortality). The only evidence for carcinogenicity in mice was an increase in the incidence of adenomas in the livers of females exposed to 28,800 mg/m^3. Although lymphocytic leukemia was reported in both controls and low-dose male rats, the summary does not state whether the leukemia incidence was greater in the low-dose males than in controls. Increases in renal tubular cell tumors were seen in the intermediate- and high-dose male rats.

Based on the summaries, evidence for the carcinogenicity of MTBE appears to be marginal. No definitive conclusions as to the likelihood of any human cancer risk can be drawn from the summaries of these studies because of the limitations listed below. The full study results are under evaluation.

- Actual data were not presented in the summaries.
- The statistical significance of any reported effects was not provided in the summaries.
- The mouse study was slightly less than a lifetime. Although an 18-mo study is not considered to be inadequate, longer exposures may have resulted in greater tumor incidences.
- The authors claimed the high dose in mice exceeded the maximum tolerated concentration, thus invalidating the results at this dose. From the data presented, it is uncertain if the maximum tolerated concentration actually was exceeded.
- Finally, the authors claimed that the kidney tumors present in exposed male rats were due to the accumulation of a protein (alpha$_{2\mu}$ globulin) in the tubule cells, an effect unique to male rats and thus not contributing to the weight-of-evidence for human carcinogenicity. In order for the EPA to accept this conclusion, the data must be evaluated to determine if MTBE meets a set of criteria listed in EPA/625/3-91-091F (EPA Risk Assessment Forum document on male rat urinary system tumors associated with alpha$_{2\mu}$ globulin).

2.2.2 Formaldehyde, Benzene, and Butadiene

All gasoline-fueled automobiles will emit formaldehyde, benzene, and 1,3-butadiene. These pollutants are of interest because of their cancer potential. Benzene is classified as a proven human carcinogen, and 1,3-butadiene and formaldehyde are classified as probable human carcinogens (Grindstaff et al., 1991; U.S. Environmental Protection Agency, 1985, 1989).[1] If concentrations of all these chemicals were equal, the estimated cancer risk of benzene and formaldehyde would be similar, but butadiene would have a higher estimated cancer risk.

As described in the scientific literature, acute exposure to formaldehyde can also cause noncancer effects (U.S. Environmental Protection Agency, 1987; Grindstaff et al., 1991). Irritation of the eyes, nose, and throat is the most common effect observed in humans from short-term exposure to formaldehyde and can be observed at exposure levels as low as 0.1 mg/m^3. Short-term exposures to 3 or 4 mg/m^3 do not produce noticeable lung effects. Formaldehyde exposure has been linked with a number of behavioral and physiological effects such as thirst, dizziness, headache, and apathy. Residents of homes in which formaldehyde concentrations ranged from 0.06 to 0.6 mg/m^3 have reported these symptoms along with an inability to concentrate and sleep. Tolerance to low levels of formaldehyde can occur in individuals after 1 to 2 h of exposure, but symptoms can return if exposure is interrupted and then resumed. It should be noted that some of the symptoms of acute formaldehyde exposure described in the scientific literature are among those included in the "case definition" for the MTBE survey of complaints found in Fairbanks and Anchorage.

Benzene and 1,3-butadiene also can cause noncancer effects in laboratory animals after subchronic or chronic exposures, but carcinogenesis is the endpoint of concern after long-term exposure (U.S. Environmental Protection Agency, 1985, 1989). Only exposure to very high concentrations (relative to likely exposure levels) of these compounds can cause acute health effects in humans, and therefore acute effects are not relevant to the oxyfuels scenario.

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[1]Benzene has a cancer classification of A, a human carcinogen based on sufficient evidence from epidemiological studies; formaldehyde is classed as B1, a probable human carcinogen based on sufficient evidence from animal studies and limited evidence from human studies; 1,3-butadiene is classed as B2, a probable human carcinogen based on sufficient evidence from animal studies and inadequate data from epidemiological studies.

3. VEHICLE EMISSIONS, AIR QUALITY, AND EXPOSURES

3.1 Vehicle Emissions

Several earlier studies performed by EPA, the Auto/Oil Program, and others have shown that MTBE oxyfuels can reduce emissions of CO in vehicles operated at and above 40 °F. However, the question arose as to how the subarctic conditions of Alaska influence CO emissions and whether adding MTBE to fuels reduces CO emissions in comparison to other climates. The data base of EPA's Atmospheric Research and Exposure Assessment Laboratory (AREAL) on the effects of temperature and the use of MTBE on CO emissions only included data obtained at temperatures down to 40 °F. To expand the data base, emissions tests were performed at temperatures of 20 and 0 °F using fuels with and without MTBE (Atmospheric Research and Exposure Assessment Laboratory, 1993). A 1984 Buick Century equipped with a carburetor was tested at 75, 40, 20, and 0 °F with a blend of 14.4% MTBE in gasoline and the base gasoline of the blend. This vehicle had been tested at 75 and 40 °F with a blend of 9.5% MTBE and the base gasoline of this blend. All tests were run in the AREAL cold-cell dynamometer using the Federal Test Procedure driving schedule.

The CO emissions for the base fuel increased with a decrease in temperature down to 0 °F. The CO emissions also increased when MTBE fuel was used, but were always lower than observed with the base fuel. The emissions of MTBE from the MTBE fuel increase with a decrease of temperature. The small amount of MTBE tailpipe emissions from the vehicle using the base fuel showed no temperature effect. Most fuels, including the base fuel, now in use contain a small amount of MTBE (2 to 4%) added as an octane enhancer.

Benzene, 1,3-butadiene, and formaldehyde emissions were also measured in the temperature-variation studies. There was a trend towards an increase in emissions of benzene, 1,3-butadiene, and, to a lesser degree, formaldehyde as temperature decreased when the base fuel was used. Generally, the addition of MTBE to the fuel reduced the exhaust emissions of benzene and 1,3-butadiene and increased the emissions of formaldehyde. The exact impact of MTBE was dependent on the temperature, and the trends for specific toxic compounds were less clear. The temperature variation studies indicate that whether the fuel has MTBE or not, there is a tendency for lower temperatures to increase the total emissions of the three air toxics and alter the ratios of the specific compounds emitted.

Generally speaking, the use of MTBE in a 15% blend reduces evaporative emissions of benzene, primarily through the substitution of an oxygenate for benzene and other aromatics.

The Auto/Oil Air Quality Improvement Research Program also examined the impact of MTBE on motor vehicle toxic emissions (Reuter et al., 1992). This work showed that, at 75 °F, emissions of benzene decrease and emissions of formaldehyde increase; 1,3-butadiene is not altered when MTBE is added.

3.2 Air Quality and Exposures

3.2.1 Air Samples

On December 19-22, 1992, the State of Alaska collected 8-h air samples in Fairbanks, which were analyzed for concentrations of aldehydes, MTBE, and other compounds at AREAL. Because MTBE use has significantly declined, new air samples are being taken for comparison purposes. Until these are analyzed, it is not possible to determine whether MTBE use influenced local air levels of the key compounds. All of the data summarized below are from these samples (Atmospheric Research and Exposure Assessment Laboratory, 1993).

Of the 26 air samples analyzed for aldehydes, seven were of outdoor air. No formaldehyde was detected in the one "pristine" air sample. At a gas station, 0.010 mg/m^3 formaldehyde was found. At five locations outside buildings and at a street corner, formaldehyde levels ranged from 0.0054 to 0.0145 mg/m^3. Indoor air concentrations ranged from 0.0001 to 0.036 mg/m^3 formaldehyde; the highest being in the sample taken inside the old post office.

Thirty-one December samples were analyzed for MTBE, total nonmethane organic carbon (TNMOC) (a standard approach to emissions characterization), and other specific compounds. In the analysis of TNMOC concentrations, no unusual compounds or concentrations were found. Toluene was the most abundant compound found in most of the ambient air samples. Overall levels of organics found in these samples are typical for urban areas.

Concentrations of MTBE indoors ranged from a trace level to 0.059 mg/m^3. The highest outdoor concentration was at a service station (0.105 mg/m^3 MTBE). Other outdoor air levels ranged from 0.0048 to 0.078 mg/m^3.

3.2.2 Air Concentrations Inside Automobiles

The Environmental and Occupational Health Sciences Institute, under an EPA cooperative agreement, recently completed a set of pilot field measurement experiments of MTBE concentrations inside automobiles in New Jersey for a simulated, 35-min suburban commute. These studies were undertaken to preliminarily examine the potential for human exposure to MTBE. The concentrations reported below serve only as an example of the potential for exposure and, at this point, are too limited to draw precise exposure estimates. A wider range of values is likely, depending on a number of variables, including the specific model and age of the automobile and the driving pattern. In New Jersey, service-station attendants fill up cars and pumps have vapor recovery systems. These factors, which do not occur in Fairbanks, Anchorage, or Missoula, may also influence concentrations of vapors within cars during and soon after refueling. Concentrations of MTBE are significantly higher close to a fill-up scenario at a gas station. The average concentrations of MTBE inside two different automobiles were 0.07 and 0.21 mg/m^3 during a commute; these levels increased to 0.36 and 1.4 mg/m^3 when a fill-up at a gas station was included in the commute. A few measurements were also conducted while at the gas station. One run showed MTBE concentrations inside one automobile to be approximately 0.11 mg/m^3 prior to the fill-up, 2.2 mg/m^3 at the gas station, and 1.2 mg/m^3 immediately after leaving the gas station. As more studies are conducted, these averages are likely to change.

Air samples collected in December over an 8-h period in Fairbanks by the State of Alaska included seven obtained inside vehicles. All concentrations were less than 0.03 mg/m^3 MTBE, with the exception of one (1.2 mg/m^3) (Schweiss, 1993).

3.2.3 Exposure Estimates of MTBE

The data on air quality and microenvironments (e.g., during refueling, inside cars, in personal garages) are too limited for a quantitative estimate of exposure. At best, they can be used to estimate approximate, broad ranges of potential exposures. Because of the interest in MTBE, the present evaluation focuses on this compound, even though any potential health effects might result from complex pollutant mixtures of which MTBE is only one component.

There is a need to estimate both acute and chronic exposures to elucidate health risks. It can be assumed that a gasoline fill-up scenario, although brief, would result in the highest acute exposure concentrations. There is inadequate information to predict this exposure concentration for a person refueling his/her own vehicle. In the preliminary New Jersey studies, where attendants pump gas, the level inside a car at a gas station during refueling was approximately 2.2 mg/m^3.

In estimating annual exposures, the amount of time an individual spends in microenvironments having different concentrations of MTBE needs to be calculated, as well as the number of months over the year MTBE oxyfuels are in use. It is likely that a worst case exposure scenario occurs over a 5-min period during fill-up (in the range of 2.2 mg/m^3). Longer mid-level exposures during commuting are likely and may be in the range of 0.21 mg/m^3. The remainder of the time would be at lower levels approximating 0.08 mg/m^3, again using worst-case available values. Because MTBE oxyfuels are only used at high levels during the winter months, very low, perhaps negligible levels would be present for most of the year. However, use of premium gasolines with MTBE would result in some residual exposures. If the available limited data are evaluated with worst-case assumptions (which also have flaws), an annual exposure might be somewhere around 0.05 mg/m^3 (Atmospheric Research and Exposure Assessment Laboratory, 1993). It cannot be overemphasized that this value is no more than a very crude estimate that may increase or decrease as more information becomes available.

4. HEALTH RISK ESTIMATES

4.1 Carbon Monoxide

The CO NAAQS is set to protect sensitive subpopulations against adverse effects, with an adequate margin of safety. The NAAQS is not a perfect "bright line", immediately below which there is absolute safety and immediately above which there is major widespread health risk. Rather, different degrees of risk occur for different subpopulations both below and above the NAAQS. The risk level below the NAAQS is expected to be essentially negligible for all individuals, except possibly a few of the most health-compromised members of the most sensitive subpopulations. A preliminary analysis of the ambient air quality in the

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